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Food Quantity and Quality for Zooplankton in the Sacramento-San Joaquin Delta

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This article is part of a series of articles describing the components of a new CALFED-supported, collaborative study of the Sacramento-San Joaquin Delta's foodweb base (see Cloern 1999).

The Sacramento-San Joaquin Delta estuary (hereafter: the Delta) with its great diversity of habitats is home to a wide variety of primary producers including algae, aquatic plants, and riparian vegetation. These primary producers, as well as organic matter brought into the Delta from the surrounding watersheds, provide the food resource for higher-order producers such as aquatic invertebrates and fish. Growth and reproduction of these consumers as well as trophic transfer efficiency in the Delta food web depend to a large degree on the quantity and quality of the available food. Due to the diversity of habitats and primary producers in the Delta, the quantity and quality of food available to consumers is likely to vary greatly.

A direct way to assess food quantity and quality is to measure the growth and reproductive rates of consumers reared on food taken from natural habitats. In our study we feed food particles present in water taken from several Delta habitats to zooplankton. The habitats include river, marsh, floodplain, and flooded island sites and are sampled several times per year. Currently we are conducting these feeding studies with laboratory cultures of the filter-feeding cladoceran *Daphnia pulex*. Due to their rapid asexual reproduction and non-selective feeding behavior, these organisms are well suited to our feeding experiments. We also intend to conduct feeding experiments with calanoid copepods, which are often very abundant in the Delta and an important food resource for fish.

Feeding experiments similar to ours have previously been used in nutritional studies of freshwater cladocerans (Müller-Navarra 1995) and estuarine copepods (Jónasdóttir and Kiorboe 1996). Results from these and other recent studies have shown the concentration of several essential fatty acids as well as elemental ratios (particularly the carbon to phosphorus ratio) in food particles to be strongly correlated with zooplankton production. We are quantifying these and other food and habitat characteristics in cooperation with researchers involved in the larger group project (Cloern 1999; Canuel 1999). To gain further insight into the nature of the food resources utilized by Delta zooplankton, we are also measuring essential fatty acid concentrations and elemental and isotopic ratios in zooplankton collected from our study sites.

The strength and uniqueness of our approach lies in combining the direct assessment of food quality and quantity through feeding experiments with more indirect assessments utilizing numerous field measurements. Results obtained from this study will contribute to a greater understanding of nutritional habitat quality for higher-order producers in general, and for Delta consumers in particular. We also expect to better understand spatial and temporal variability of food quality and quantity for Delta zooplankton. For example, initial results suggest that when flooded, the Yolo Bypass may be a more productive habitat for zooplankton than the Sacramento River, and thus provide richer feeding grounds for young fish. Findings from our study will provide information critical to policymakers and agencies responsible for management of the Delta and its resources.

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Delta Smelt Concerns Result in Changes in SWP and CVP Operations

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State and federal export facility operations were modified in May and June in response to concerns over the distribution and high salvage of delta smelt at the SWP and CVP Delta pumping facilities. Since we have no direct measure of delta smelt losses at these facilities we use salvage of delta smelt as a surrogate for "take." 1999 was an above-normal (San Joaquin Basin) to wet (Sacramento Basin) water year (DWR 1999), but the distribution of young-of-year (YOY) delta smelt was more typical of a dry year hydrology with a greater proportion of the population remaining in the Delta through spring and early summer. It is uncertain why delta smelt remained in the Delta for so long this year, but water temperature may have been an important factor (Dale Sweetnam, personal communication).

Delta smelt spawn in areas of fresh water under tidal influence. In dryer years, spawning is often concentrated on the Sacramento River side of the Delta, especially in the Cache Slough area. In wetter years, spawning is widespread and can occur as far west as the Napa River, as it did this year. Similar to 1997, a large YOY delta smelt population in the central Delta resulted in higher take at the SWP and CVP facilities. The elevated take levels were surprising since this year's Delta hydrograph showed a similar pattern to 1996 (Figure 1). Delta exports were considerably higher in late May and June 1996 than they have been this year, yet delta smelt salvage in 1996 was less than half of the 1999 levels (Figure 2).

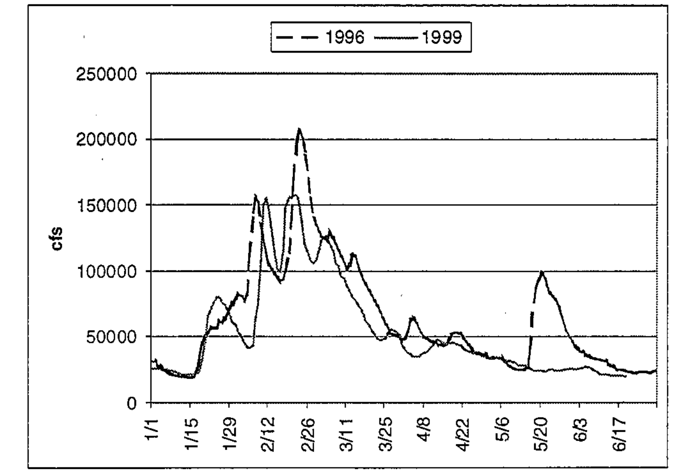

Figure 1 Delta inflow in 1996 and 1999

The US Fish and Wildlife Service biological opinion dealing with the effects of SWP and CVP operations on delta smelt uses two levels of combined SWP and CVP delta smelt salvage as triggers to initiate actions to reduce water project impacts on delta smelt. These thresholds include the following:

- The 14-day running average of combined delta smelt salvage, commonly referred to as the yellow light level.
- The cumulative total of combined salvage for each month, commonly referred to as the red light level.

The red light level is based on historical salvage data and varies among months and among water year types. For example, in an above-normal water year (like 1999) the red light level ranges from 733 fish in December to 11,990 fish in October. Monthly red light levels for below-normal water years are generally higher than for above-normal water years.

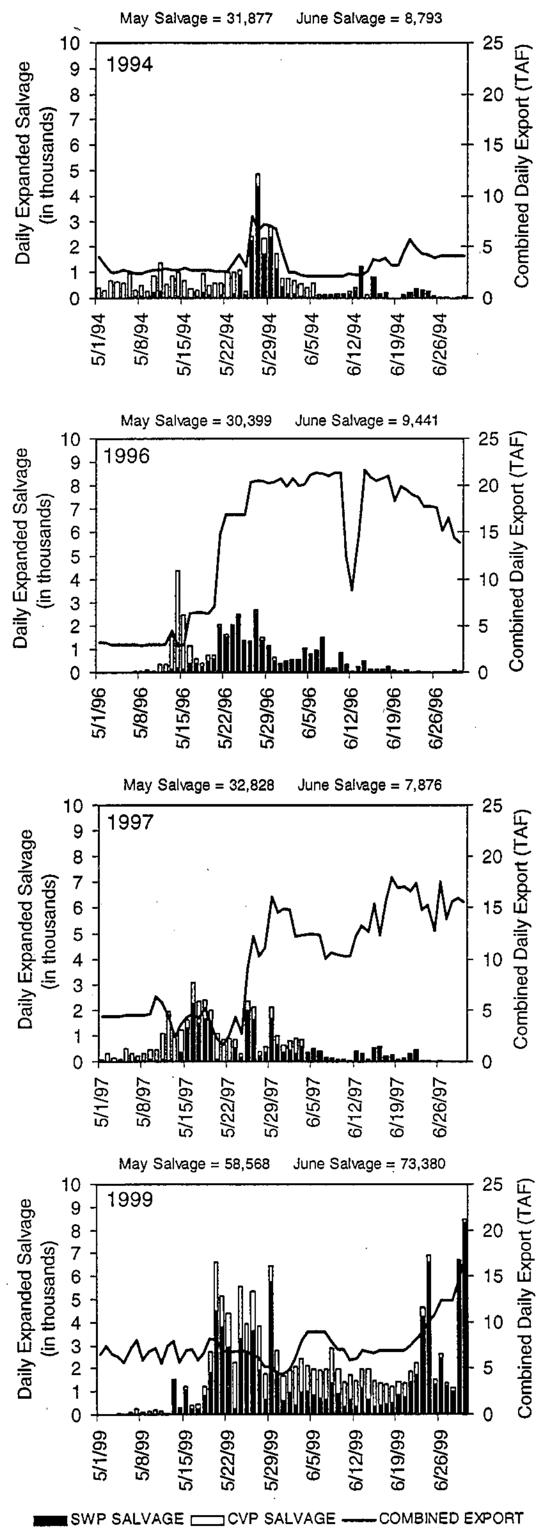

Figure 2 State and federal delta smelt salvage from May through June during the last four years that take exceeded a red light level. The daily red light level for any given month in 1994 was 400. For all subsequent years, the monthly red light level for May was 9,769 and for June was 10,709.

In 1999, the combined CVP and SWP delta smelt salvage increased dramatically during May. Only delta smelt longer than 20 mm are considered to be "take" in the salvage operations. The yellow light level was exceeded by 18 May, and the red light level (9,769 delta smelt) was exceeded by 16 May. Combined salvage remained high throughout the month, and by the end of May total monthly salvage (58,568 delta smelt) exceeded the red light level six fold.

Take remained high in June as well. The June red light level (10,709 delta smelt) was exceeded by 6 June. By the end of June, combined monthly salvage (73,380 delta smelt) exceeded the red light level by nearly seven fold. During the past six years the projects have exceeded the red light level in May four times (see Figure 2), but this is the first year the projects have exceeded the red light level two months in a row. This year's June salvage is particularly anomalous since delta smelt have usually moved downstream by June. June salvage this year exceeded the previous high of 45,913 delta smelt salvaged in June 1981.

Maintaining low export levels has been the primary action for minimizing delta smelt take this year. Substantial export reductions have occurred. By the end of June, exports were more than 400,000 acre-feet lower than what would have occurred in the absence of delta smelt concerns. Export/Inflow (E/I) ratios have ranged from about 9% to 22% during May and most of June. The E/I ratio did not approach the 35% limit specified by the delta smelt biological opinion until June 28. Two south Delta temporary barriers have been operational (Middle River and Old River near Tracy). The Grant Line Canal barrier is in place, but it is being held open to reduce reverse flow in Old River.

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Wind and Rough Weather Decrease Captured Delta Smelt Survival

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Delta smelt, *Hypomesus transpacificus*, is a small, threatened osmerid, native to the Sacramento-San Joaquin Delta. Laboratory studies on delta smelt, such as the Fish Treadmill Project (Swanson and others 1998), are usually limited by fish availability and transport survival. Because of their highly delicate nature, delta smelt survival after collection, handling and transport has been unpredictable even with consistent handling methods. This study aimed at determining the environmental factors that affect the 24 and 48 h survival of delta smelt in the laboratory, after collection, handling, and transport from the Delta.

Methods

Delta smelt were collected from various sites in the Sacramento-San Joaquin Delta from July to November 1997, and from August to December 1998 (specific conductance ranging from 200 to 2,000 µmho/cm) using a 40 m long, 4 m deep, 2 mm mesh purse seine—similar to method in Swanson and others (1996). At the end of each set, the pursed net was pulled to one side of the boat and fish were removed from the net using a polyethylene bag dip net and placed in a bucket with 4 to 6 ppt salinity and 0.5 ml/L NovAqua. Addition of salt and NovAqua, a synthetic polymer, to transport medium was intended to reduce stress-induced osmotic imbalance. Fish were counted and placed into vertical polyethylene bags containing 10 L of estuary water with 4 to 6 ppt salinity and 0.5 ml/L NovAqua. Four bags were set inside a 60 L plastic chest cooler on top of 10 cm polyurethane foam sheet. After the bag was stocked with fish (maximum: 50 per bag), the air in the bag (about one-third of its volume) was squeezed out and replaced with medical-grade oxygen and the bag sealed. A thin layer of crushed ice was placed outside the bags to maintain the water temperature ±1 °C. However, during late fall and early winter, when the Delta water temperatures were below 10 °C, we did not put crushed ice on the transport bags, and temperature in the bag did not increase >0.5 °C during transit. Variables such as date, time of collection, temperature, specific conductance, weather, wind, surface water, and total smelt collected were noted. Survival data were available for 16 collection days in 1997 and 26 collection days in 1998. During the second year of the study, an outer black polyethylene bag was used over the translucent transport bag to reduce light, and another 10 cm polyurethane foam sheet was placed inside the plastic chest cooler to reduce agitation. Additionally, length of transport time (water transport, land transport, and total transport) was also noted on 18 collection days of the second year.

Upon arrival at the Aquatic Center at the Institute of Ecology (University of California, Davis), temperatures of the transport bags and the 250 L holding tank were remeasured. Holding tanks were supplied with non-chlorinated, air-equilibrated, temperature-controlled well water with brine drip system to maintain tank water at 4 to 6 ppt. When holding tank temperature was higher than the transport bag, 4 to 5 gallon size bags with crushed ice were floated on the holding tank until the temperature in the bags and tank were equilibrated before releasing the fish into the tank. Holding tank water was maintained at 4 to 6 ppt salinity by a brine drip system and 10 ml of NovAqua was added before the fish were released into the tank. The tank was enclosed with black plastic to minimize illumination and disturbance. Dead fish in the tank were removed and measured each day. The rest of the fish were fed with *Artemia* nauplii (1,000 nauplii per liter) twice a day and a commercial diet (Biokyowa, Inc.) throughout the day.

Percent survival was calculated 24 h (day 1) and 48 h (day 2) after collection. Besides a least squares regression analysis, a principal component analysis (PCA) was conducted because of significant correlations ($P < 0.05$) among some of the variables. We used orthogonally rotated data on factors that explained 95% of the variation of the original set of independent variables. Data for 1997 and 1998 were pooled for statistical analyses because the significant regressors ($P < 0.05$) showed similar trends for both years.